ENP100 - Prosess og produksjon

Øving 8 - Løsningsforslag

Oppgave 1 a)

- Same diameter = no velocity difference; kinetic term = zero
- Frictional term for two parts; pipe + valve

$$\Delta p = p_1 - p_2 = \underbrace{\rho g H}_{\text{Hydrostatic}} + \underbrace{\frac{1}{2}\rho\left(\frac{4\cdot\dot{Q}}{\pi D^2}\right)^2\cdot\left[\underbrace{f_D\cdot\frac{L}{D}}_{\text{Pipe}} + \underbrace{\xi}_{\text{Valve, same nominal Diameter}}\right]}_{\text{Friction}}$$

$$\rightarrow \Delta p = 1000\frac{kg}{m^3}\cdot\left(9.81\frac{m}{s^2}\cdot 15\,m + \frac{1}{2}\left(\frac{4\cdot 0.04\,m^3/s}{\pi\cdot(0.13\,m)^2}\right)^2\cdot\left[0.02\,\frac{73\,m}{0.13\,m} + 1.5\right]\right)$$

$$= 204958\,\underbrace{\frac{kg}{m^3}\cdot\frac{m^2}{s^2}}_{= N/m^2} \approx \underline{\underline{2.05\ bar}}$$

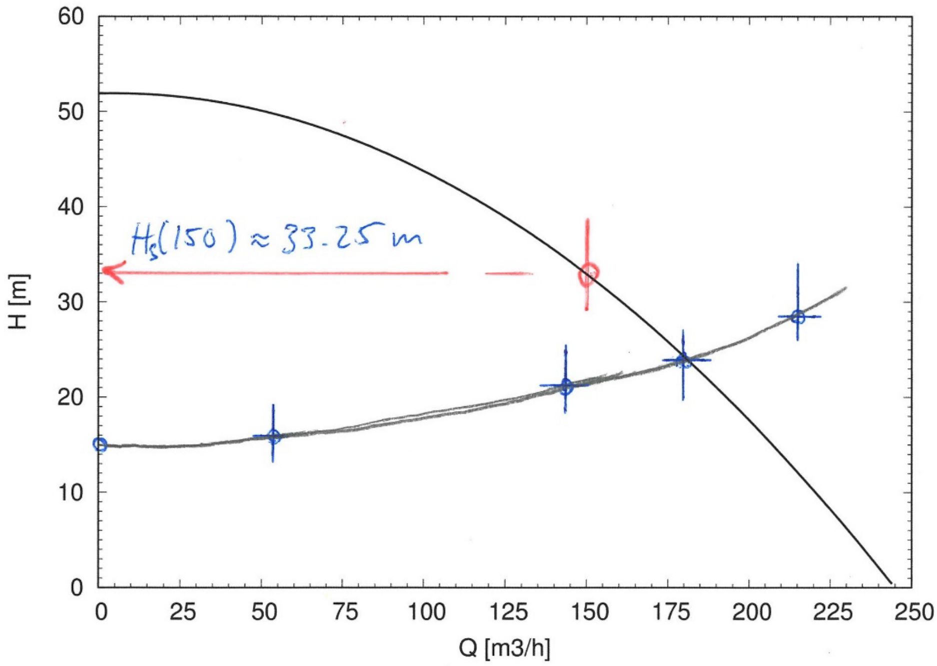
b) Rewrite the equation for calculating the system head (Hs) as a function of flow more efficiently, and/or use a spreadsheet to calculate some extra points.

$$H_s = \frac{\Delta p}{\rho g} = H + \frac{8}{g\pi^2 D^4}\left[f_D\frac{L}{D} + \xi\right]\cdot\dot{Q}^2 \quad \dot{Q}\,[m^3/s]$$

(For Q = 0 Hs = H, and for Q = 144 m3/h, divide the result from a) by ρ · g. Also; for hand calculation choose "calculator friendly" values of Q)

Q [m3/h]	Q [m3/s]	Hs [m]
0	0	15
54	0.015	15.83
144	0.04	20.89
180	0.05	24.21
216	0.06	28.26

Plot these in with the characteristic curve, and read off the value: In this case, the point for Q = 180 m3/h practically matches the pump charactersistic. <u>Qn ≈ 180 m3/h</u>



c) For the pump to deliver exactly 150 m3/h, a system head corresponding to the pump head at that rate is required. This can be read of the pump diagram; Hs (150 m3/h) ≈ 33.25 m.

Then solve the equation for Hs w/ respect to ζ, and convert the flow rate to m3/s:

$$\zeta = \frac{g \pi^2 D^4 \cdot (H_s - H)}{8 \dot{Q}^2} - f_D \frac{L}{D}$$

$$\dot{Q} = 150 \, m^3/h = 0.04167 \, m^3/s$$

$$\Rightarrow \zeta = \frac{9.81 \cdot \pi^2 \cdot 0.13^4 \cdot (33.25 - 15)}{8 \cdot 0.04167^2} - 0.02 \cdot \frac{73}{0.13} = \underline{\underline{25}}$$

Oppg. 2 — Compressor

a) Want answers in mass units — convert the gas constant:

$$M_w = \gamma_g \cdot 29\ \text{g/mol} = 0.68 \cdot 29 = 19.72\ \text{g/mol}$$

$$R = \frac{R_0}{M_w} = \frac{8.314\ \text{J/mol K}}{19.72\ \text{g/mol}} = 0.4216\ \text{J/gK} = \underline{421.6\ \text{J/kgK}}$$

$$P_1 v_1 = RT_1 = 421.6 \cdot \underbrace{(36 + 273.15)}_{309.15\ K} = \underline{130338\ \text{J/kg}}$$

Compression work, closed volume:

$$W_c = \frac{RT_1}{k-1}\left[\left(\frac{P_2}{P_1}\right)^{\frac{k-1}{k}} - 1\right] = \frac{130338}{0.24} \cdot \left[\left(\frac{8}{2.5}\right)^{\frac{0.24}{1.24}} - 1\right]$$

$$= \underline{\underline{137116\ \text{J/kg}}}$$

b) Assume constant pressure and volume:

Work pr. mass unit is simply the product of $P_2 \cdot v_2$

(Easiest to find using $P_2 v_2 = RT_2$, T_2 from 11.41:

$$W_b = R \cdot T_2 = R \cdot T_1 \cdot \left(\frac{P_2}{P_1}\right)^{\frac{k-1}{k}}$$

$$= 421.6 \cdot 309.15 \cdot \left(\frac{8}{2.5}\right)^{\frac{0.24}{1.24}} = \underline{\underline{163245\ \text{J/kg}}}$$

c) Compression work, open system:

$$W_s = RT_1 \frac{k}{k-1}\left[\left(\frac{P_2}{P_1}\right)^{\frac{k-1}{k}} - 1\right] = 130338 \cdot \frac{1.24}{0.24}\left[\left(\frac{8}{2.5}\right)^{\frac{0.24}{1.24}} - 1\right]$$

$$= \underline{\underline{170023\ \text{J/kg}}}$$

Optional :

a) * Work to displace compressed gass refers to unit mass

→ $W_b = 163245$ J/kg

* Work to compress refers to 1.3 x that amount

→ $W_c = 1.3 \cdot 137116 = 178251$ J/kg

in total : $W_c + W_b = 341496$ J/kg

b) * Suction work pr. mass unit is product of

$p_1 v_1 = RT_1 = 130338$ J/kg $= W_s$

* Work to expand gas in clearance volume is the Same as compression work, but refers to

$\dot{m}_e = \dot{m}_c - \dot{m} = 1.3 - 1 = 0.3$

→ $W_e = 0.3 \cdot 137116 = 41135$ J/kg

in total : $W = W_c + W_b - W_s - W_e$

$= 178251 + 163245 - 130338 - 41135 = 170023$ J/kg